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OPTIMIZATION OF PROCESS PARAMETERS FOR SPOT WELDED En19 STEEL

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ABSTRACT

Resistance spot welding plays an important role in the field of manufacturing of cars, buses and railway bodies etc. It also has significant importance in the field of manufacturing due to automation and quick processing. There are many key factors that controls this process of RSW such as current, time, electrode force, contact resistance, property of electrode material and surface conditions etc. In this research work, the effect of three major welding parameters such as pressure, weld time and current in resistance spot welding of EN19 steel were considered. An EN19 steel sheet (100mm*30mm*6mm) was considered for welding of lap joint. Based on Response surface methodology (RSM), the experiments were conducted. For the comparison of weldability of each experimental group tensile shear strength was measured. The optimum level settings and the major parameters that influence the joint strength were obtained by the Response Surface methodology. The experiments were conducted to validate the optimum parameter settings.

***KEYWORDS:** Resistance Spot Welding (RSW), Weld Pressure, Weld Current, Weld Time, Response Surface Methodology & Tensile Shear Strength*

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Original Article

INTRODUCTION

Resistance welding is one of the fusion welding process in which a joint is welded by applying which both heat and pressure. There are three types of resistance welding processes that are classified as Resistance Spot Welding, Resistance Seam Welding and Projection Welding in which when heat is generated at the joints by the contact resistance to the flow of electric current, coalescence of metal is produced at the faying surface. Forces are applied before, in between and after the application of current in order to prevent arcing at the faying surfaces and also during the post heating process of forging the welded metal. Resistance spot welding is one among the resistant welding method which is used to join two or three overlapping metal sheets, studs, projections, electrical wiring hangers, some heat exchanger fins and tubing. A G. Thakur, V M Nandedkar [1**]**, have studied about the effects of process parameters on tensile shear strength of resistance spot welded joint of austenitic stainless steel AISI 304 using Taguchi method. Ugur Esme [2], have studied about the effects of welding parameters on the tensile shear strength of resistance spot welding (RSW) process. The experimental studies were conducted under varying electrode forces, welding currents, electrode diameters, and welding times. A. G. Thakur, T. E. Rao, M. S. Mukhedkarand V**.**

M. Nandedkar [3] has done the experimental investigation on optimization of Tensile Shear (T-S) strength of RSW for Galvanized steel by using Taguchi method. Luoyi, [4] have developed a mathematical model for predicting the nugget diameter and tensile shear strength of galvanized steel. The input parameters that are added to the experimental work are preheating current, weld current, weld time and welding pressure.

Major factors which control this process are welding current, welding time, electrode force, contact resistance, properties of electrode material, sheet materials, and surface condition etc. The quality of the spot welded joints is defined by the mechanicSal properties and the size of the heat affected zone. The weld strength is measured by a number of standardized destructive tests, which subjects the weld to different types of loading [5-8]. Some of these are tension-shear, tension, torsion, impact, fatigue and hardness.

Controlling these welding parameters plays an important role on the quality of the weld. This study gives a systematic approach in determining the effects of process parameters (Welding Pressure, Welding Time and Welding Current) on tensile shear strength of resistance spot welded joint of EN19 steel using Response Surface Methodology (RSM). During the nugget formation, copper alloys are used to apply welding pressure and convey the welding current through the work piece. In the spot welding process, after putting a sufficient amount of energy into the weld zone to raise the material to the solidus-liquidous temperature of the materials to be bonded a welded nugget will start to form and hence to begin the formation of a melted weld pool [9-11]. EN19 alloy steel has high tensile strength, high quality and good ductility, shock resisting properties combined with resistance to wear.

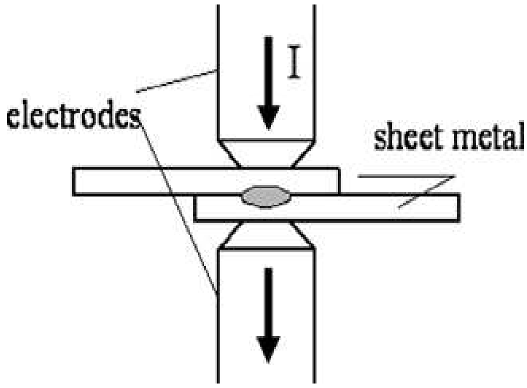

Figure 1: Diagrammatic Representation of the Resistance Spot Welding Process.

The typical unconformities of spot welds are,

Cold weld,

Small-diameter nugget,

Bad shape of welding nugget,

Cracks inside/around welding nugget,

Deep indentation of welding electrodes in sheets.

HEAT GENERATION

By passing the current through a conductor, the electrical resistance of the conductor to current flow will cause the heat to be generated. The amount of heat generated in this process is governed by the formula,

$$\mathbf{Q = I^2 RT}$$

Where

Q = Heat generated, Joules

I = Welding Current, Amperes

R = Resistance of the work piece, Ohms

T = time of current flow, Second

PRESSURE

The effect of pressure on the resistance spot weld should be carefully considered. The primary purpose of pressure is to hold the parts to be welded in intimate contact at the joint interface. This action assures consistent electrical resistance and conductivity at the point of weld. The tongs and electrode tips should not be used to pull the work pieces together. Before the application of the pressure, the parts to be welded should be in intimate contact with each other.

CURRENT

The size of the weld nugget and in fact whether it will form or not depends upon the heat being generated faster than it is dissipated by conduction. Welding current is, thus, the most critical variable. The voltage can be low but the current is very high (thousands of amperes). Metals can be joined by this process using both alternating and direct current.

RESPONSE SURFACE DESIGNS

Box-Behnken design

Central Composite Design

CENTRAL COMPOSITE DESIGNS

There are two types of central composite designs in response surface design, namely uniform precision and orthogonal. These properties of central composite designs relate to the number of center points in the design and to the axial values:

Uniform Precision means that the number of center points is chosen so that the prediction variance at the center is approximately the same as at the design vertices.

Orthogonal Designs, the number of center points is chosen so that the second order parameter estimates are minimally correlated with the other parameter estimates.

Table 1: EN19 Steel – Chemical Composition

C	Mn	Si	Cr	Mo	P	S
0.37	0.57	0.37	1.1	0.24	0.40	0.40

Table 2: EN19 Steel – Physical Properties

Sl. No.	Properties	Values
01	Density	7700 g/m³
02	Poisson's ratio	0.27 – 0.3
03	Thermal Conductivity	16.2 W/m. K
04	Thermal Expansion	17.5x10-6 /K
05	Modulus of Elasticity	185 GPa

Table 3: EN19 Steel – Mechanical Properties

Sl. No.	Property	Value
01	Tensile Strength	749.6 MPa

02	Yield Strength	591.2 MPa
03	Elongation	011.97 %
04	Hardness Vickers	248
05	Rockwell Hardness	100

EXPERIMENT DESIGN

A combination of both statistical and mathematical techniques that is used to analyze, design a model, and optimize the processes is known as Response Surface Methodology (RSM). The main purpose for using this method is to establish an unknown relationship that exists between the independent variables (input factors) and the process responses. Surface experiments are performed to fit either with a first order model (linear function) or with a second-order model of observations.

The efficiency of the response surface analysis is significantly influenced by selecting the proper choice of experimental designs. The selected input parameters are welding current, welding time and welding Pressure and the output parameters are predicting the tensile shear strength of welded joint. The input parameters are shown in table – 4.

Table 4: Levels of Process Parameters

Parameters	Notation		Range And Levels		
	Natural	Coded	-1	0	+1
Pressure (bar)	A	X1	3.8	4.6	5.4
Current (A)	B	X2	6	7	8
Weld time (cycles)	C	X3	6	8	10

The base metal with 6 mm thickness has been cut into the required size (100mm×30mm×6mm) using shearing machine and specimen have been prepared to fabricate RSW joints.

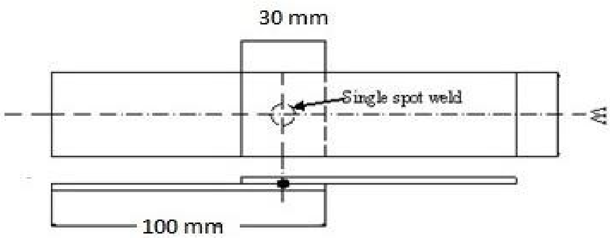

Figure 2: Dimension of Specimen.

Fabrication of Joints

In the industrial world today, the widely used oldest and electric welding technique is resistance spot welding. Using this metal joining process, the weld is made by a combination of some parameters such as heat energy, pressure energy, and time. Resistance welding implies, that it is the resistance of the material that causes a localized heating in the part that has to be welded with the help of electric current. Pressure is exerted by the tongs and electrode tips, through which the current flows and also holds the parts to be welded in intimate contact before, during, and after the welding current cycle time. The amount of time required for the current flow in the joint is determined by type of material, thickness of the material, amount of current flowing across and the cross-sectional area of the welding.

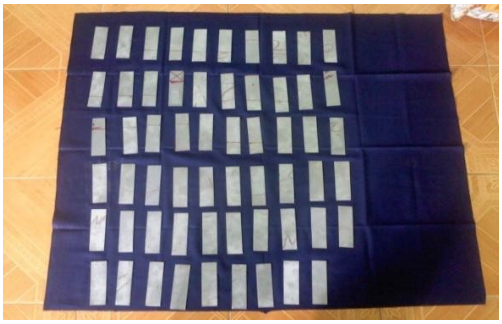

Figure 3: Specimen Before Welding.

Figure 4: Welded Specimen.

Table 5: Experimental Data of Tensile Strength

Exp. No.	T-S Load for Specimen 1(KN)	T-S Load for Specimen 2 (KN)	Average T-S Load (KN)	T-S Strength (N)
1	3.6	3.0	3.3	2266.7
2	7.8	7.8	7.8	3193.3
3	8.0	8.2	8.1	5666.7
4	3.8	3.8	3.8	7040
5	7.6	7.6	7.6	8440
6	7.8	8.4	8.1	8200
7	6.6	6.8	6.7	8340
8	3.4	3.6	7.0	8676.7
9	6.8	7.0	6.9	3810
10	3.4	7.6	5.5	4280
11	6.8	8.4	7.6	7265
12	4.0	7.4	5.7	6296.7
13	3.6	8.0	5.8	7370
14	6.8	7.0	6.9	8693.33
15	3.8	7.4	5.6	8116.67
16	3.4	8.4	5.9	8626.67
17	8.6	8.4	8.5	8940
18	7.0	6.8	6.9	6450
19	3.4	6.8	5.1	7303
20	3.6	6.8	5.2	7986.67

Table 6: Regression Co-Efficient for T-S Strength

Terms	Co-efficient	Se Co-efficient	T	P
Constants	9314.1	660.7	14.096	0.00
Block	613.32	567.9	1.08	0.308

A	1990.01	701.4	2.837	0.019
B	771.64	322.4	2.393	0.04
C	-29.2	304.8	-0.096	0.926
A*A	596.7	600.8	0.993	0.347
B*B	-2567.8	713.0	-3.602	0.006
C*C	-961.2	481.6	-1.996	0.077
A*B	-845.02	322.4	-2.621	0.028
A*C	-40.1	376.1	-0.107	0.917
B*C	-1404.6	353.1	-3.978	0.003

RESULTS AND DISCUSSIONS

Experimental data's for tensile shear strength have been noted. The experimental data's are given as input for calculating the results of the main effects of tensile shear strength of RSM method using MINITAB software. Investigation of the welding parameters that significantly affects the performance characteristics is carried out by analyzing the variance. This process is accomplished by separating all the total variables of the grey grades that are measured by the sum of square deviation from the total mean into contributions of each cutting parameters and errors. This research is all about the usage of general linear Model ANOVA in determining the percentage of influence of welding pressure, welding current and welding time on tensile shear strength of the weldments.

Table 7: ANOVA Table for T-S Strength

CF	DoF	SS	V	F-Ratio	% of C
A	2	15775276	4971658	18.74	2.9
B	2	51576655	53436734	201.4	31.2
C	2	51576655	30463356	114.82	17.8
A*B	4	9376812	35070745	132.2	41.0
A*C	4	20610859	576559	2.17	0.7
B*C	4	21588983	1473382	5.55	1.71
Error	62	9149439	265339		4.8
Total	**80**	**76501369**			**100**

SS – Sum of Squares; DoF – Degree of Freedom; V –Variance; % of **C** – Percentage of Contribution.

Table – 7 shows the ANOVA table corresponding to the tensile strength. This table shows the main effects and significance of weld pressure, welding current and welding time with respect to tensile strength.

Influence of Process Parameters on Tensile Shear Strength

Table 8: Contributions of Individual Parameters on Tensile Shear Strength S = 1008, R – Sq = 88 %

Source	DoF	SS	Contribution (%)
Welding Pressure	2	3045.82	34.8
Welding Current	2	5338.25	61.0
Welding time	2	2241.52	25.6
Error	13	580.41	6.63
Total	**19**	**8746.5**	**100**

Table – 9 shows the General Linear Model ANOVA table that is corresponding to the tensile strength. The percentage of contribution of welding pressure, welding current and welding time on tensile shear strength is shown in this

table. The welding current and welding pressure has a maximum influence on the tensile shear strength with the contribution of 61.0%, and 34.8% respectively, followed by 25.6% of the welding time. Weld time influences the tensile strength in a very less amount.

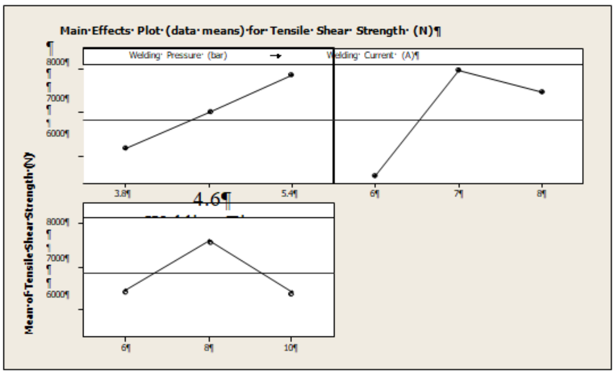

Figure 5: Tensile Shear Strength Influenced by Various Process Parameters.

Optimizing the Process Parameters

After analyzing the mean value of each experiment a better combination of parameter levels are obtained. Mean response is the average value of the performance characteristics of each parameter at different levels. The Mean was also calculated by obtaining the averages of all responses of that level. Later for each parameter at level 1, 2 and 3 the mean response of raw data and tensile shear strength for were calculated. An analyzes of the means of various process parameters was done from which it is observed that larger values correspond to a better quality characteristics.

Table 9: Optimum Parameters and Levels

Weld Pressure (Bar)	Weld Current (A)	Weld Time (Cycles)
5.4	8	8

Confirmation Test

Confirmation test is the final step of first iteration using design of the experiment. The Confirmation test is carried out in order to evaluate and confirm the conclusions that are drawn during the analysis phase. By conducting a test with a specified combination of the factors, the confirmation test is done. Mainly in this research work, the determination of optimum conditions and prediction of response is carried out under these conditions, after which a new test was designed and performed with the optimum level of welding parameters [10].

Table 10: Confirmation Test Results

Weld Pressure (Bar)	Weld Current (A)	Weld Time(Cycles)	T-S Strength (N)
5.4	8	8	8940.00

The experiment was conducted and average tensile shear load for optimal setting = 8.5 KN which is higher than the experimental results shown in the table- 5.

CONCLUSIONS

Hence, the conclusion of this research work includes the study of the effects of process parameters. The parameters that were considered during this research work were welding pressure, welding current and welding time. Analyses of the

experimental results were made using Response Surface Methodology and ANOVA using Minitab 14 software. According to ANOVA, the tensile shear strength of the joints produced has a very high influence of the steady welding current used in this process of welding. The other parameters have lesser contribution over the tensile shear strength of the joints made. The optimum conditions for getting a very high tensile shear strength are weld Pressure = 5.4 (bar), Weld current =8 (A) and Weld time = 8 (cycles). The confirmatory test has been carried out with optimum parameter setting and the results are validated. The experimental results have confirmed that RSM method will be applicable to enhancing a good welding performance and for optimizing the welding parameters of resistance spot welding operation.

REFERENCES

1. *A G Thakur, V M Nandedkar, September 2010, "Application of Taguchi method to determine resistance spot welding conditions of austenitic stainless steel AISI 304", Journal of Scientific & Industrial Research, vol.69, pp.680-683.*
2. *Ugur esme, October 2009,"Application of taguchi method for the optimization of resistance spot welding process the Arabian journal for science and engineering", Vol 34*
3. *A G Thakur, T. E. Rao, M. S. Mukhedkarand V. M. Nandedkar, November 2010,"Application of taguchi method for resistance spot welding of galvanized steel" ARPN Journal of Engineering and Applied Sciences, Vol 5*
4. *Karci F, kacar R & Gunduz S, (2009),"The effect of process parameters on the properties of spot welded cold deformed AISI 304 grade austenitic stainless steel", J Mater process technol,209,4011-4019*
5. *"Sensitivity Analysis of TIG Welding Parameters for ASTM- 500 Grade B Weldments", International Journal of Applied Engineering Research and Development, Vol. 6, Issue 1, pp. 1-10*
6. *Kim H R & lee K Y, (2009)," Application of taguchi method to determine hybrid welding conditions of aluminium alloy", J Sci Ind res, Vol 68, 296-300*
7. *Murat Vural, Ahmet Akkus, (2004), "On the resistance spot weldability of galvanized interstitial free steel sheets with austenitic stainless steel sheets". Journals of material processing technology, page 153-154.*
8. *"Corrosion Fatigue of Welded Joints in Marine and Naval Structures: A Review", IJMPERD, Vol. 7, Issue 5, pp. 155-162*
9. *P. J. Ross, 2005, "RSM Techniques for Quality Engineering", Tata McGraw Hill, second edition.*
10. *J. Lantz, February, (2000), "Principles of Resistance Welding", Welding Design and Fabrication, pp. 46–49.*
11. *S. Fraley, M. Oom, B. Terrien, and J. Z. Date, 2006, "Design of Experiments via Response surface methodology, TheMichigan Chemical Process Dynamic and Controls Open Text Book.*
12. *"Microstructural Evolution and Mechanical Properties of MIG Welded AA6061 Aluminum Alloy", IJMPERD, Vol. 10, Issue 1, pp. 709–718*
13. *Balaji, D. S., S. Prabhakaran, and K. Umanath. "multi-objective optimization in abrasive water jet drilling of aa6061 alloy."2017.*
14. *"Corrosion Behavior of Copper–Alumina Nanocomposites in Different Corrosive Media", International Journal of Mechanical Engineering (IJME), Vol. 5, Issue 6, pp. 1-10*
15. *Sivaram, A. R., Vinoth kumar, V., Umanath, K., Sarathkumar, P., Rajavel, R., Optimization of machining parameters in wire cut edm using taguchi techniques, Journal of Advanced Research in Dynamical and Control Systems, 9(2 Special Issue), pp. 883-897, 2017.*